Ensuring Payload Safety on Missions Involving Special Partnerships

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ABSTRACT

The National Aeronautics and Space Administration (NASA) Expendable Launch Vehicle (ELV) payload space flight missions involve cooperative work between NASA and partners including spacecraft (or payload) contractors, universities, nonprofit research centers, Agency payload organization, Range Safety organization, Agency launch service organizations, and launch vehicle contractors. The role of NASA's Safety and Mission Assurance (SMA) Directorate is typically fairly straightforward, but when a mission's partnerships become more complex, to realize cost and science benefits (e.g., multi-agency payload(s) or cooperative international missions), the task of ensuring payload safety becomes much more challenging. This paper discusses lessons learned from NASA safety professionals working multiple-agency missions and offers suggestions to help fellow safety professionals working multiple-agency missions.

1. INTRODUCTION

The National Aeronautics and Space Administration (NASA) routinely collaborates with partners including spacecraft (or payload) contractors, universities, nonprofit research centers, Agency payload organization, Range Safety organization, Agency launch service organizations, and launch vehicle contractors. NASA depends on the Expendable Launch Vehicle (ELV) Payload Safety Program to manage the Agency's interests in safety and mission success for these joint efforts.

NASA's ELV Payload Safety Program was originally developed in response to events that occurred during the Cloud-Aerosol LIDAR and Infrared Pathfinder Satellite Observation (CALIPSO) mission. CALIPSO can be seen in Figure 1. CALIPSO was a joint science mission between NASA Langley Research Center (LaRC), Goddard Space Flight Center (GSFC), and Centre National d'Etudes Spatiales (CNES). This multi-agency mission between NASA and CNES was also a dual payload mission since CALIPSO was launched with CLOUDSAT, another cloud and aerosol observer satellite. CloudSat used a Cloud Profiling Radar (CPR) instrument, a 94-GHz nadir-looking radar, to measure the power backscattered by clouds as a function of distance from the radar. The design of the CPR was developed jointly by NASA Jet Propulsion Laboratory (JPL) and the Canadian Space Agency (CSA).

Figure 1. CALIPSO spacecraft

CALIPSO demonstrates well the importance and challenges of performing cross-agency safety engineering and safety coordination. As the mission progressed, concerns were raised involving design requirements that threatened to delay the mission. One of the biggest challenges of joint missions is meeting multiple sets of safety requirements, especially those that cross agencies. However, in this particular case, the disagreement primarily existed within NASA. Alcatel Space Industries manufactured the off-the-shelf, hydrazine-fueled Proteus propulsion bus used by CALIPSO. CNES provided the spacecraft bus as part of their in-kind contribution to the joint mission. Even though NASA JPL had used the Proteus propulsion bus for a previous oceanography mission, Jason-1, without a safety concern, GSFC Safety and Mission Assurance (SMA) believed that the threaded fittings in the Proteus propulsion system did not meet NASA fault tolerance design guidelines. SMA at JPL and other NASA Centers did not necessarily agree with GSFC SMA's position.

The existing payload safety review and approval process at the time was not sufficiently prepared to handle GSFC SMA's safety concern with CALIPSO's Proteus bus. A safety concern that should have been addressed at a much lower level of decision-making was left unnoticed until late in processing, and the NASA Chief of SMA, Center Directors, Air Force Range Safety, CALIPSO Project Manager, and other upper level managers were forced to intervene to resolve the issue. Ultimately the NASA Engineering and Safety Center (NESC) was brought in to independently assess the Proteus propulsion bus threaded fittings safety concern, and the NESC generated a report with recommended safety requirements to aid in the safe processing of CALIPSO (RP-04-01/03-001-E) and future Proteus bus missions.

2. NASA'S ELV PAYLOAD SAFETY PROGRAM

NASA recognized an opportunity for improvement following CALIPSO and established NASA's ELV Payload Safety Program in May 2008 to ensure the safety of personnel and resources from hazards associated with NASA payloads flying on unmanned ELVs. The Program does not cover safety during flight operations or payloads going to the International Space Station. The Program seeks to improve NASA safety review and approval process, and delineates clear roles and responsibilities for those involved in ensuring payload safety. The Program also improves and formalizes NASA's payload safety review and approval processes, establishes formal decision-making authorities, and clarifies a process for handling dissenting opinions.

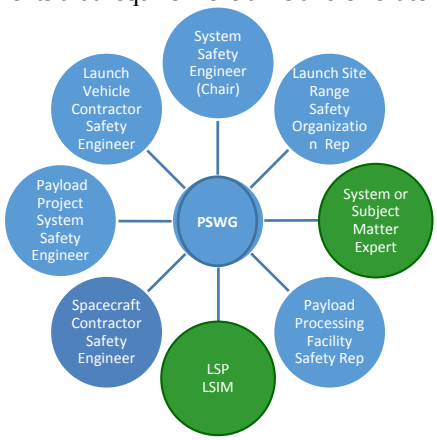
NASA's ELV Payload Safety Program consists of a fulltime ELV Payload Safety Manager with a safety engineer support contractor and a part-time Agency Team. Agency Team members are payload safety managers located at GSFC, NASA Headquarters, JPL, Kennedy Space Center (KSC) and Wallops Flight Facility (WFF). The Agency Team helps ensure consistent application of payload safety requirements across the Agency for NASA ELV payloads.

NASA's ELV Payload Safety Program has two primary documents. The first, a NASA Procedural Requirements document, NPR 8715.7, Expendable Launch Vehicle Payload Safety Program, provides the payload safety review and approval process and related roles and responsibilities. The second is a NASA Standard, NASA-STD 8719.24, NASA Expendable Launch Vehicle Payload Safety Requirements, written jointly with U.S. Air Force Range Safety since most NASA payloads are launched from the Air Force's Eastern and Western Ranges. A joint Air Force/NASA team tailored AFSPCMAN 91-710, Range Safety User Requirements and incorporated applicable NASA safety requirements to form NASA-STD 8719.24.

3. METHODS UDRF TO FACILITATE SAFE AND SUCCESSFUL NASA ELV PAYLAOD MISSIONS

While multi-agency and international cooperative missions offer challenges, the benefits justify the effort. International cooperation is a cornerstone principle of NASA's activities and has been part of NASA since its inception. The 2010 National Space Policy of the U.S. of America lists as one of the goals to expand international cooperation on mutually beneficial space activities. The benefits from leveraging partner funding and capabilities through multi-agency missions are numerous. Cooperative research objectives between partners can be efficiently accomplished with access to an increased number of talented engineers and scientists. Additionally, the overall cost of research can be shared and reduced while facilitating wider distribution of research and science data. It is easy to see why multi-agency missions will continue, especially in years of smaller agency budgets.

Agencies wishing to benefit from cooperative missions have several hurdles to overcome to ensure safety and mission success. While participants in joint partnership have individual goals, it is important to realize that all members have the same basic objective: a safe and successful launch of the payload. In working toward that goal, the safety requirements used by all members of the joint effort are similar. It is the coordination and communication of the payload safety review and approval process and the resolution of non-similar safety requirements that require more time and effort to resolve.



Recognizing this, partners need to understand that performing payload safety for joint missions requires a different approach than missions involving a single agency. Most importantly, partners need to recognize that time, as much as an additional 50% or more, is required to overcome the challenges associated with joint missions. Challenges include:

- Confirming that all safety concerns have been addressed. With varying levels of experience in joint missions, it may take time to define and explain roles and responsibilities and educate about payload safety requirements and safety review processes.
- Coordinating between multiple Centers, contractors, and agencies and facilitating necessary safety discussions.
- Multiple lines of management may need to review and approve mission processes.
- Communication between partners is not always easy to accomplish when international partners work cooperatively, and basic communication can become difficult when language barriers exist.
- Small misunderstandings can halt progress, and upper-level managers of partner organizations working toward milestone goals do not want these items to become show-stoppers that delay launch operations.
- There are financial and legal aspects to consider, and establishing contracts and agreements takes time.

NASA ELV Payload Safety has implemented processes to avoid these common pitfalls.

3.1 Payload Safety Working Group

The standing Payload Safety Review Panel used by Shuttle Program was expensive to maintain but worked well for a program with funding to support it. NASA ELV Payload projects do not have funding to support a standing panel, so a more cost-effective, mission-specific Payload Safety Working Group (PSWG) is formed for each NASA ELV payload project. The PSWG is made up of safety engineers representing the various organizations involved in the mission. These typically include the payload project system safety engineer, the payload contractor safety engineer, the launch site range safety engineer, the launch vehicle contractor system safety engineer, the payload processing facility safety engineer, and the NASA Launch Services Program system safety engineer who often chairs the PSWG. *Figure 2* shows the typical members of a PSWG in blue with green indicating specialists that may be called in to assist when needed.

Figure 2. Payload Safety Working Group

Each mission generally has four safety review milestones in which the PSWG is involved. Additional review meetings may be held depending on the complexity and hazards related to the mission. It is not uncommon to hold several meetings to complete one of these safety reviews. The safety review process is kicked off with a Payload Safety Introductory Briefing (PSIB) held early in the preliminary design phase. The PSIB is followed by Safety Review I occurring around the Preliminary Design Review (PDR), Safety Review II held around the Critical Design Review (CDR), and Safety Review III completed prior to shipping the payload to the launch site processing area.

The payload organization provides safety data packages to the PSWG for review in accordance with the mission-specific tailored NASA-STD 8719.24 Annex. Hazards are identified and abated to the satisfaction of the PSWG members. When the PSWG has issues or needs assistance, the ELV Payload Safety Program Agency Team is available to step in and help. Hazards are identified and documented along with agreed-to abatement actions on Hazard Reports (NASA Form NF 1825). Open safety verification actions are tracked until closed on a Safety Verification Tracking Log (SVTL).

NASA's ELV payload safety review and approval process finishes with the signing and distribution of the Mission's Certificate of ELV Payload Safety Compliance. From this point forward, local safety professionals, most of whom were on or represented on the PSWG, ensure safety during payload processing operations in their jurisdictions and the SVTL is closed out.

3.2 Trilateral Safety and Mission Assurance Payload Safety Task Force

The European Space Agency (ESA), Japanese Aerospace Exploration Agency (JAXA) and NASA established a Trilateral SMA in 2008 to enhance the success of our cooperative programs. At the first Trilateral SMA Conference in April 2008 (TRISMAC 2008), a recommendation was made to establish a Payload Safety Task Force (PSTF) to compare payload safety requirements used by the agencies. NASA hosted the first PSTF meeting in April 2009 at the Kennedy Space Center. Since then, PSTF meetings (mostly telephone conferences) have occurred. The U.S. Air Force participated in some of these meetings. To date the meetings have focused on general payload safety and

fault tolerances, propulsion and pressure systems safety requirements, pyrotechnics safety requirements, and payload safety review processes.

In general, the payload safety requirements used by ESA, JAXA and NASA, including the U.S. Air Force, were similar. A hazard is a hazard regardless of where you are in the world or in space. Fault tolerance requirements are largely the same once agreement is reached on hazard level classification (catastrophic, critical, or marginal). Hazardous energies and materials used in the spacecraft (payload) and payload processing are recognized, addressed, and abated in similar fashions. Each agency has a comprehensive safety review and approval process with some slight differences. NASA uses a mission-specific PSWG safety review approach composed of the safety engineers involved in the mission. JAXA uses a standing System Safety Review Panel (SSRP) approach where the SSRP is staffed by SMA engineers and experts. Both safety review and approval processes achieve similar results.

4.0 LESSONS LEARNED FROM MULTI-AGENCY MISSIONS

Many of the lessons learned by NASA's experience are applicable to any organization participating in joint missions. Addressing the following common obstacles allows these organizations to optimize the benefits of cooperative missions.

4.1 Early Planning

As in any mission, planning is needed to allow for a viable safety review and approval process. For multi-agency missions, expect (and plan) to spend more time on planning. The mission safety professional must initiate planning, coordination, and communication activities with their mission partners involved in safety early in the project life cycle.

The mission safety engineer should try to be involved in the development of the mission contracts and cooperative agreements to ensure appropriate safety program requirements will be included and implemented. If this is not possible, the safety engineer should review and understand the existing contracts and cooperative agreements. Mission safety professionals should consider writing additional agreements to aid in the safety review process when needed or feasible. These safety agreements should define roles, responsibilities, processes, and schedule. An agreement could even be used to bring in third party support or expertise to augment the safety team and the safety review process.

Plan to establish temporary agreements allowing contractors to converse and communicate with international team members early in the process. For the United States and often other nations performing international work, contractors are required to have a signed Technical Assistance Agreements (TAA) approved by the U.S. Department of State. Without agreement documents, contractors are not authorized to talk directly to international team members. Processing the TAA approvals may require six months to one year, so early submittal of the TAA request is recommended. Additionally, most space agencies and companies require nondisclosure agreements signed by team members and management.

By establishing your safety review team and review processes, obtaining required facility access training, and obtaining necessary TAAs to comply with any local launch site requirements, these common causes of delays can be avoided.

4.2 Export Control Considerations

International Trafficking Arms Regulations (ITAR) must also be managed. Meeting ITAR regulations involves:

- Understanding governing regulations
- Training safety team members
- Identifying possible avenues for ITAR violations
- Establishing contacts and dialog with ITAR experts and legal representatives
- Applying early for export licenses

There are four organizations that work internationally to prevent and control the export of anything used for making or delivery of nuclear chemical or biological weapons. Missile Technology Control Regime operates as one of those four organizations staffed by multiple countries from the United Nations. Rocket technology falls under the category of missile delivery systems. Specifically International Trafficking Arms Regulations (ITAR) state the restrictions on missile technology. U.S. Department of State's responsibility includes ITAR.

ITAR expands to twenty-five categories. Training personnel on ITAR specifics concerning their work is extremely important. Companies and agencies often create ITAR education for their personnel. NASA Export Control Program further educates, regulates, and monitors ITAR applying to NASA programs and

projects. Projects with international involvement or having plans to transfer information internationally require an export license outlining and documenting specific information for transfer. Allowing access to missile technology information in any media violates ITAR.

Many methods exist for export other than transfer of an actual physical item. Telephone calls, data transmission, casual conversation, and presentations are considered export of information. ITAR violations may result in harsh consequences including company fines, individual fines, and jail sentences. Verifying nationality status for members in the partnership is crucial to prevent ITAR violations. Enacting an export control plan within mission teams helps prevent accidental violation of regulations. Laziness and ignorance, not only malicious intent, could lead to illegal technology transfer. Proper ITAR planning and vigilance will allow for ITAR and payload safety compliance while maintaining mission schedule.

The following ITAR-related actions are recommended in planning an international project:

• Read governing regulations, and effectively train personnel
• Identify possible avenues for ITAR violations
• When possible, employ an export control expert or consult an expert
• Apply early for export licenses from state department or governing authority
• Keep information concerning regulated items on secure controlled date storage devices
• Contact lawyers or export control experts when questions arise in the duration of the mission

4.3 Coordinating, Communicating, and Documenting

Multi-agency missions require additional coordinating and communicating to complete the safety review process for the payload. Frequently it is necessary to perform increased documentation control as well.

Face-to-face meetings are very beneficial when communicating with other nationalities. Approximately 70% of communication is from body language. In-person meetings allow for body language and clearer verbal communication thus aiding in bridging the communication and cultural differences. However, face-to-face meetings with another space agency that require international travel are often infeasible. NASA uses videoconferences with good results with international partners. For all meetings, additional administrative planning and coordination time is necessary to connect with the desired parties. Emails and written correspondence are used regularly, but they may not be the most effective way to resolve safety concerns.

Documentation control in cooperative projects is also imperative. Only designated individuals should control and update documentation that is stored in a central repository available to appropriate partners. Personnel access to current versions of mission safety related documents must be controlled while being available to safety representatives for individual review. Recording meeting minutes and making them available for the attendees of inter-agency meetings has proven to be an effective way of providing clearer understanding of actions, roles, and responsibilities.

5.0 CONCLUSION

Over the years, NASA has gained valuable payload safety experience related to multi-agency missions through developing joint requirements with the U.S. Air Force (NASA-STD 8719.24), working with the Trilateral SMA PSTF, working multi-U.S. agency missions, and working multi-national agency missions with other space agencies. NASA has observed that payload safety engineering professionals of all agencies tend to have the same primary objective – safe payload processing and launch leading toward mission success. However, meeting this objective takes more time—more time for planning, for coordinating safety reviews, understanding contracts and agreements, for communications and cultural differences, for establishing trusted and respected safety relationships, and to allow for additional training or to bring in a third party consultant. It is our passion for safety and our respect of our fellow safety professional that motivates us to give the extra time it takes to ensure safe and successful multi-agency missions.

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